Combining Performance Modeling and Risk Analysis: A Homeland Security Case Study

Bojan Cukic, Jesse Mussgrove

Lane Department of CSEE
West Virginia University

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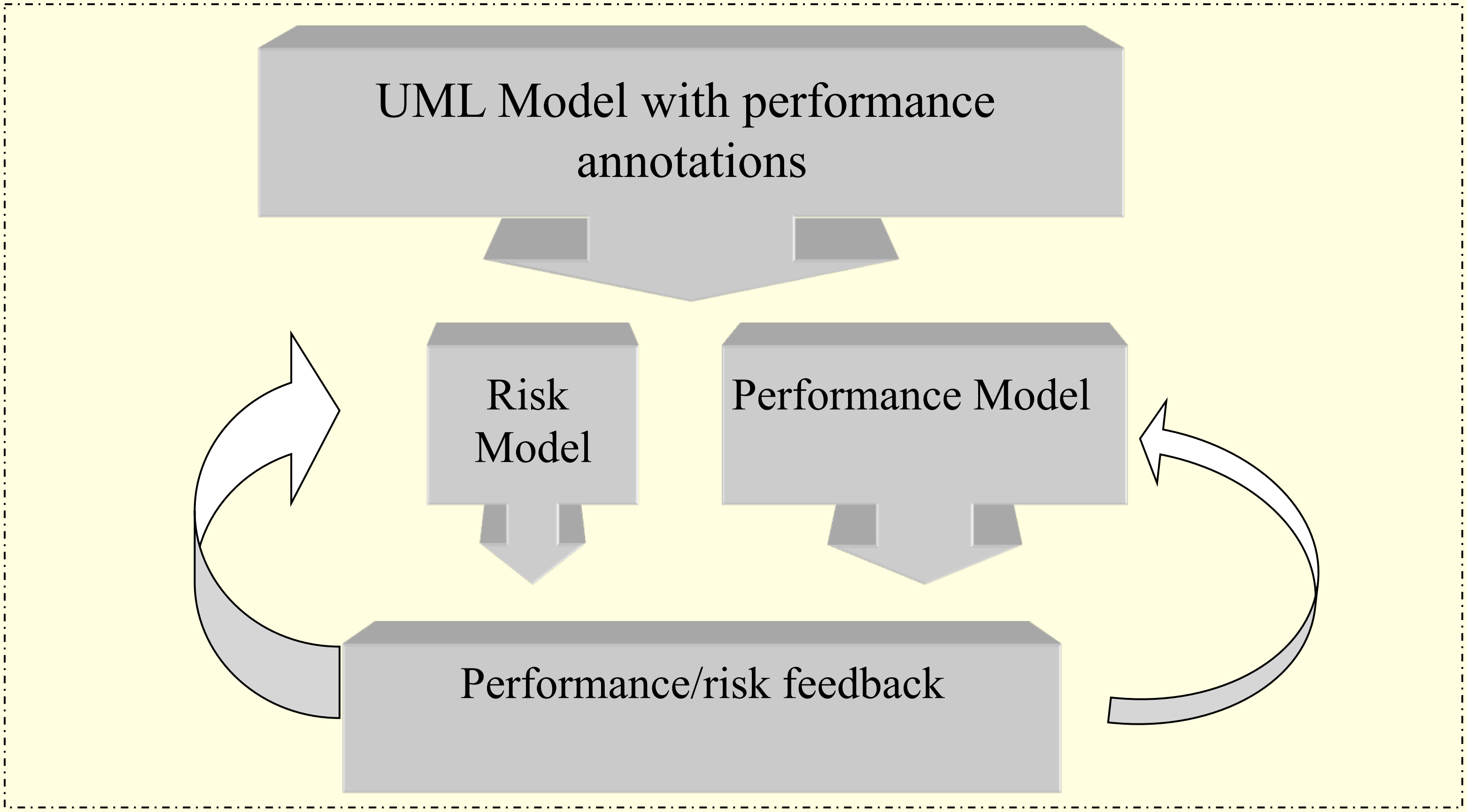
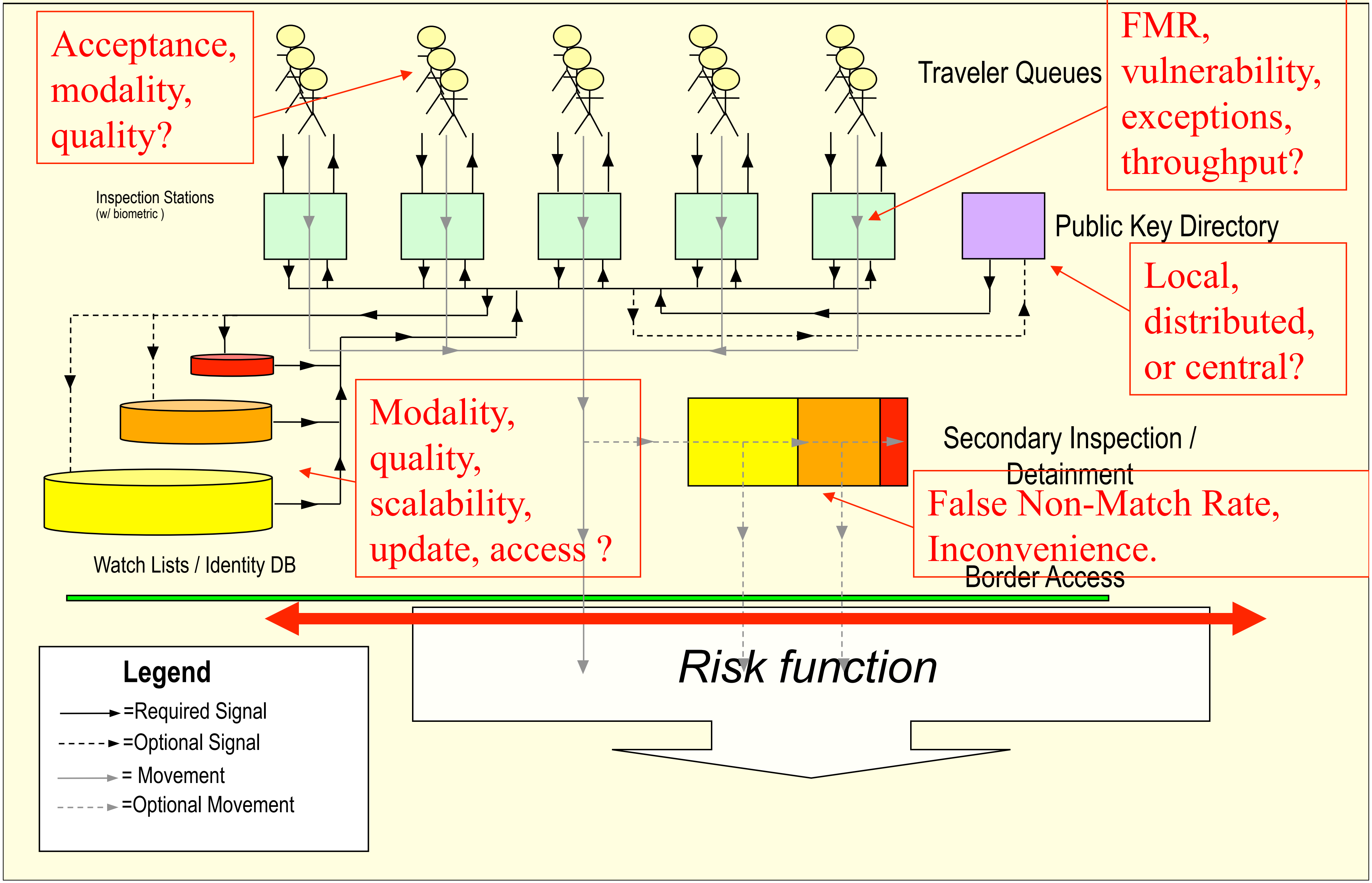
Motivation

- **At the system level, performance analysis is an essential part of verification and validation.**
  - Recent use of IV&V on complex networks and ECTP.
- **Performance and security are always interrelated.**
  - Performance implications of security risk minimization are essential.
  - Combined modeling approaches are rare.
    - Cortellessa *et al.*: Component interaction analysis.
    - Petriu *et al*.: Aspect oriented approach, primary and secondary models.
- **Complex methodology developed for a DHS study.**
  - Modeling principles applicable to IV&V practice.

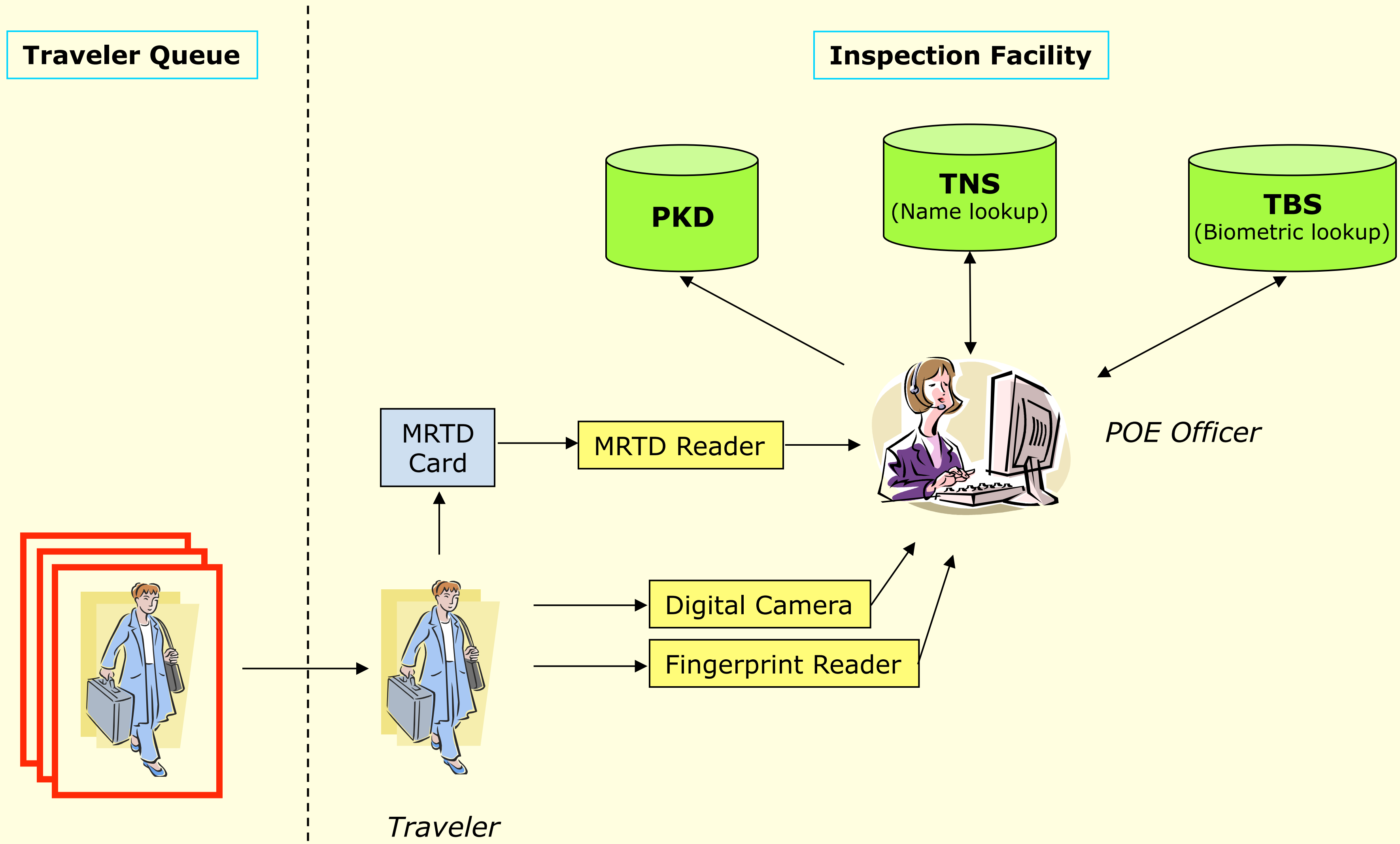
Proposed Framework



Domain: Border Management



An Airport Inspection System

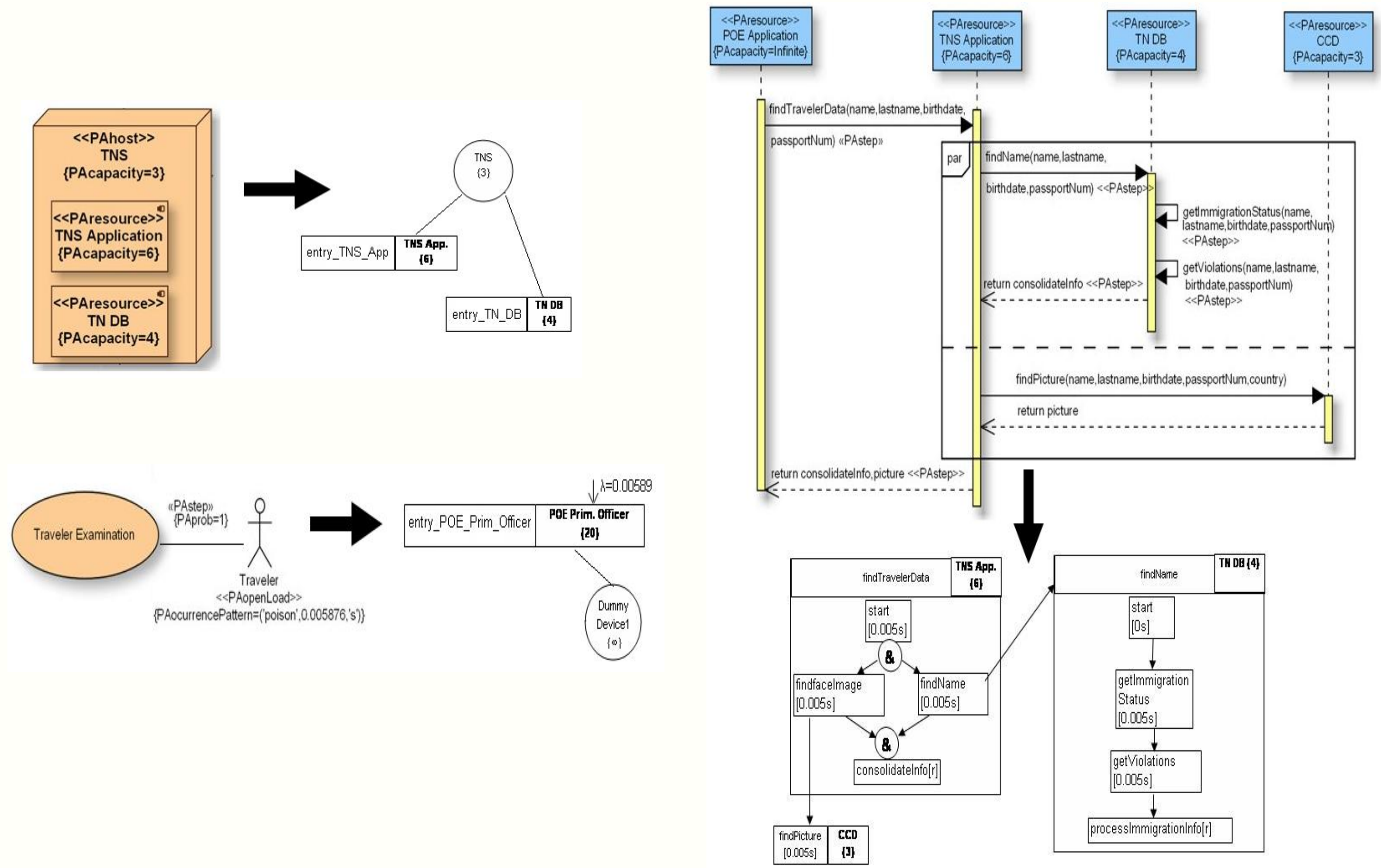


Approach

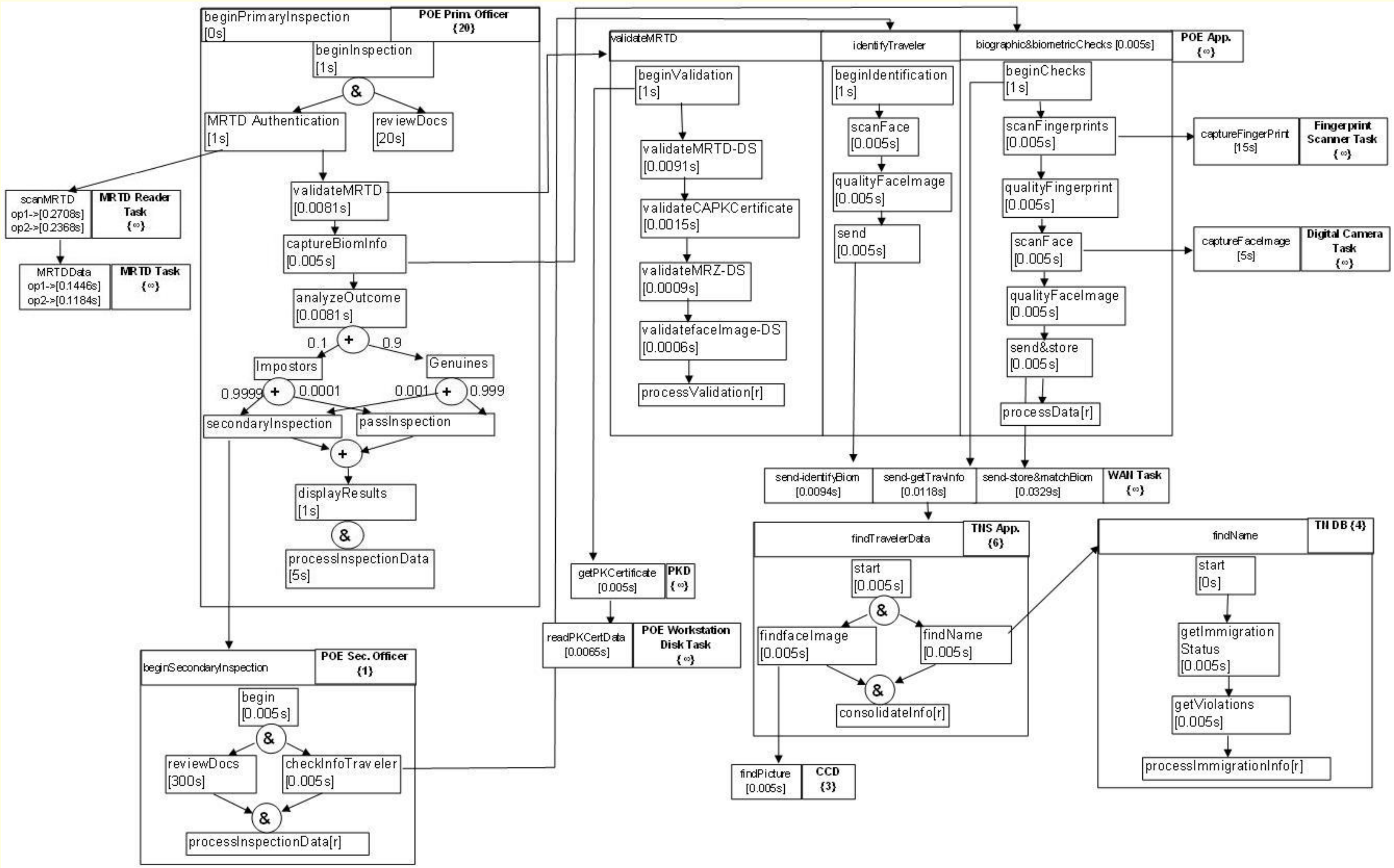
- **System architecture is nontrivial**
  - Static and dynamic architectural aspects using UML.
  - Creation and evaluation of quantitative performance models using LQN.
- **Risk analysis**
  - Border security systems rely on identity verification.
  - Validity of traveler's biometric information.
  - Checks through *watch lists.*
  - *Cost Curve modeling.*

Performance Analysis

- **UML mapping to LQN performance model**



LQN Model: Traveler Examination



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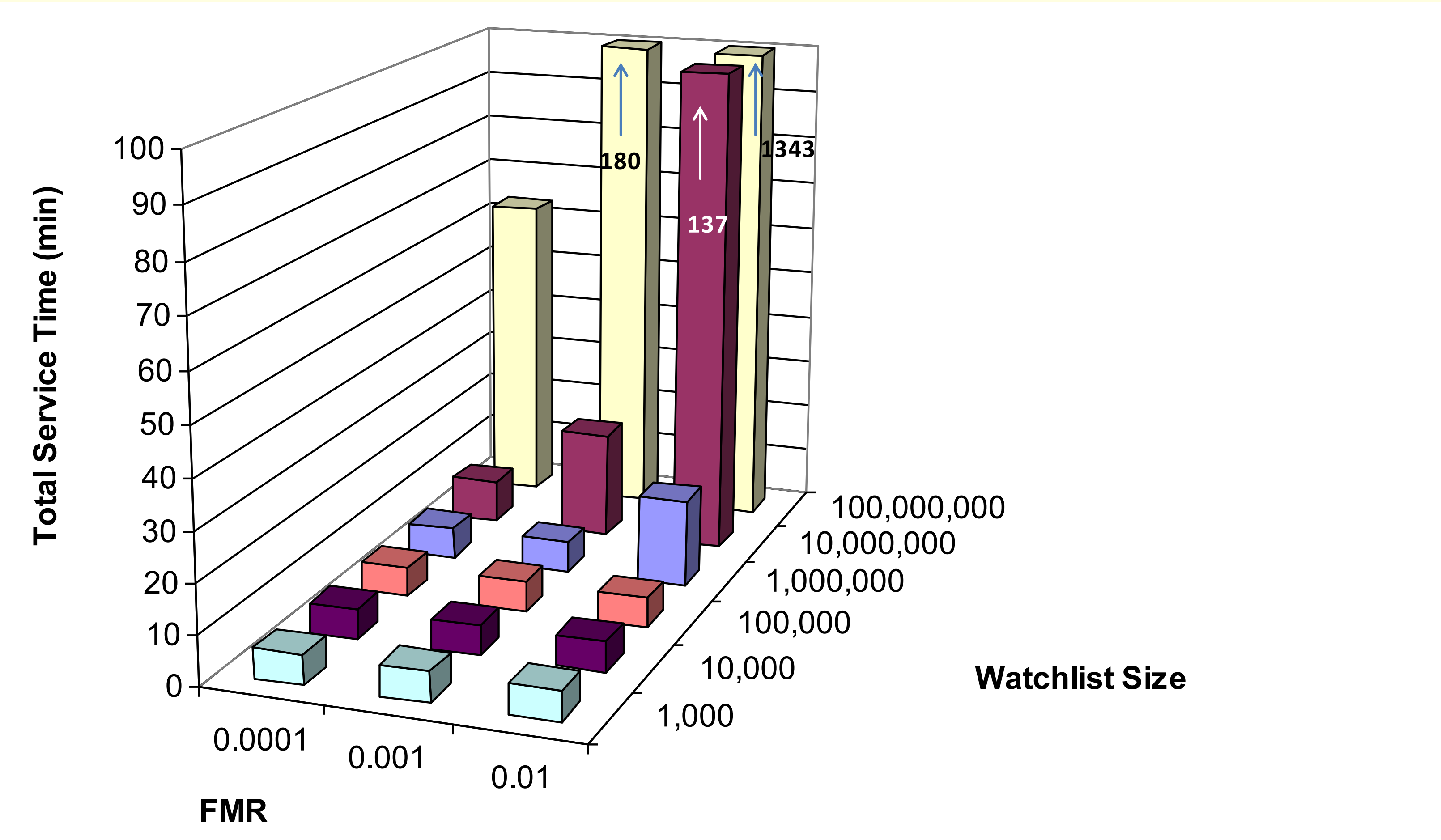
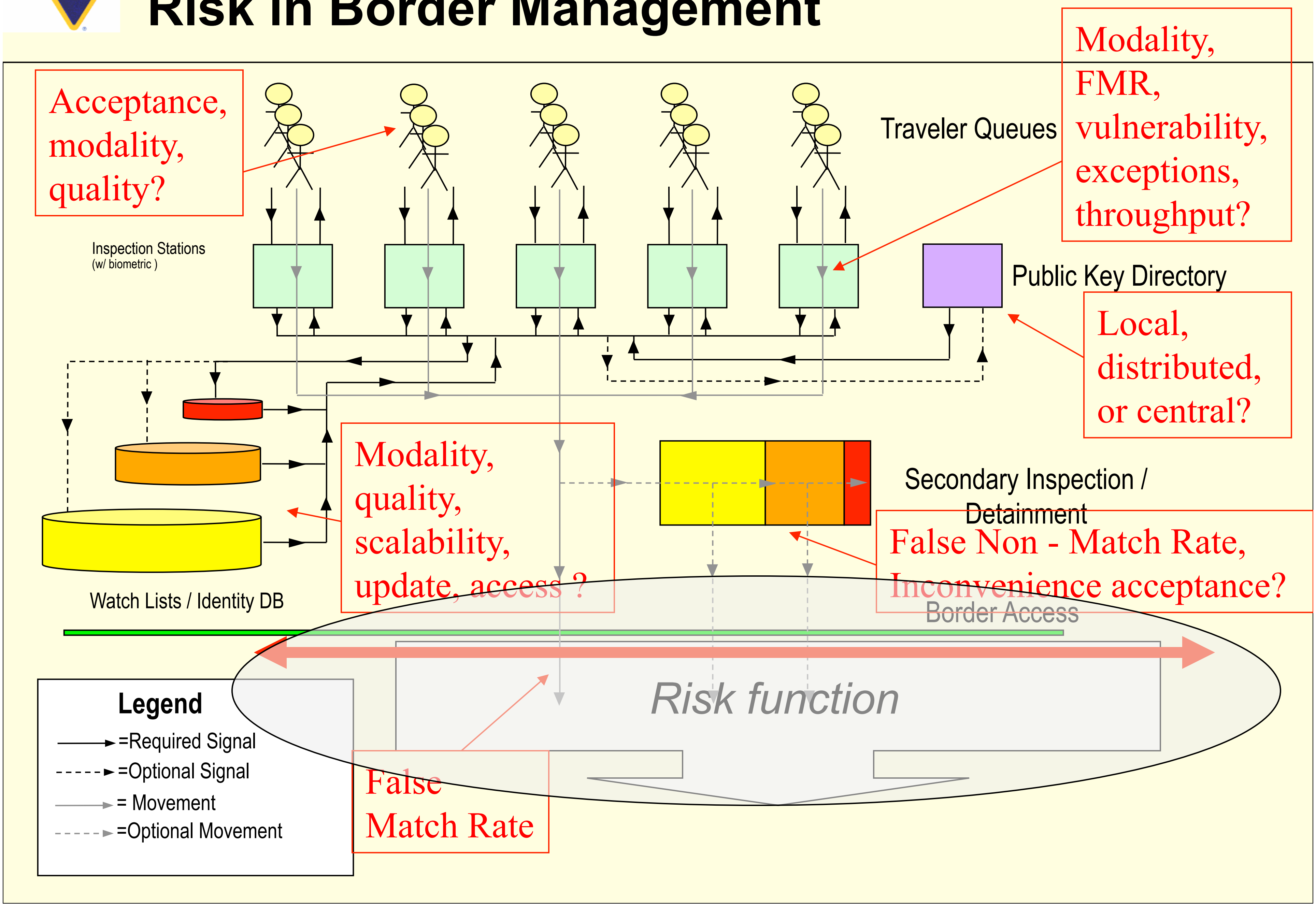
Experiments Match rates & watch lists



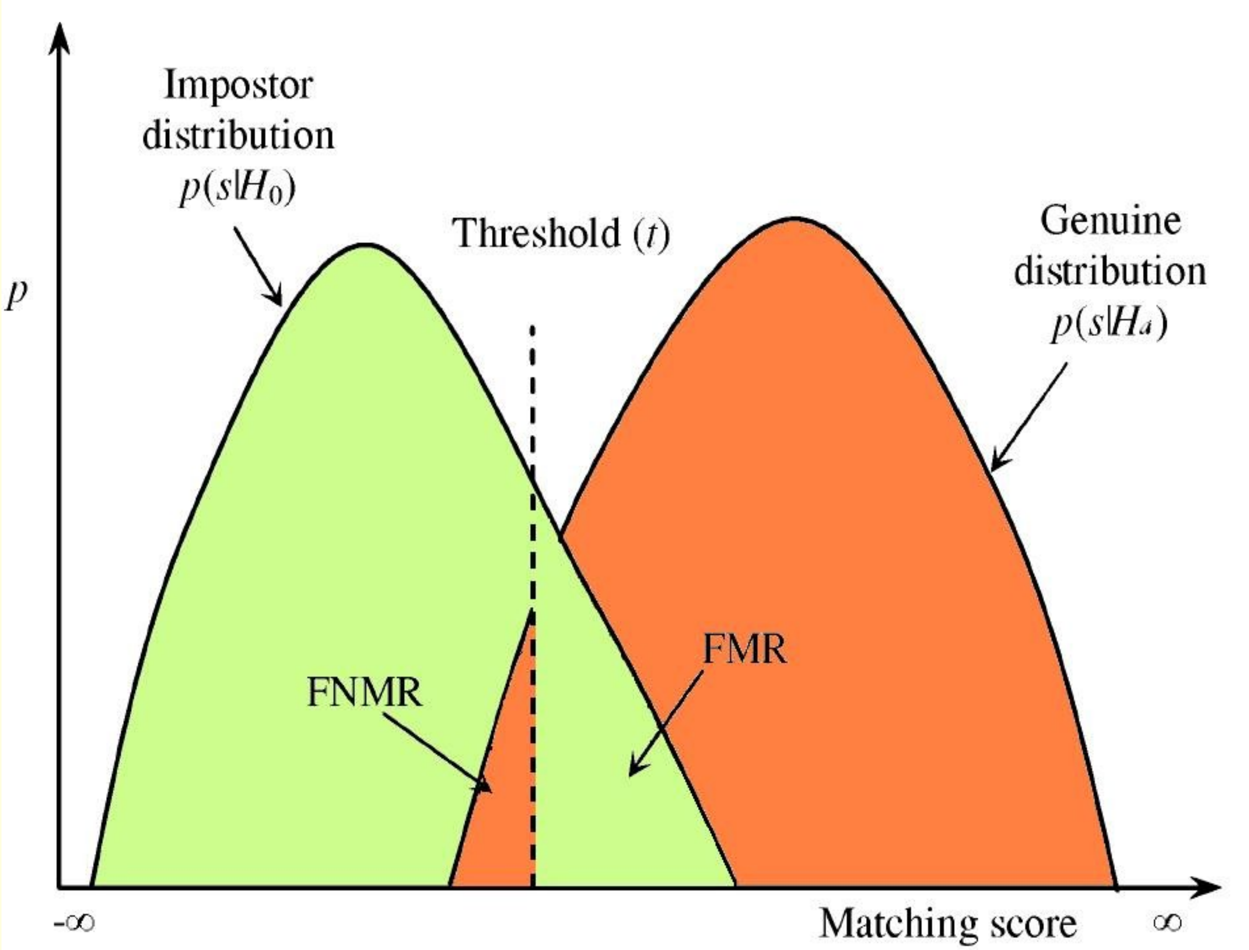
Performance Analysis

- **Performance models are derived from specifications.**
  - Tedious, semi-automatic, but well justified analysis steps.
  - Performance analysis exposes architectural limitations.
- **Watch-list size affects the system performance.**
  - Knowing the limits *early* <u>helps plan for contingencies</u>.
  - "Rapid" screening not a goal by itself.

Risk in Border Management



Why biometric systems err?



FMR – Security Risk

FNMR – Performance Burden

Cost Curve Modeling

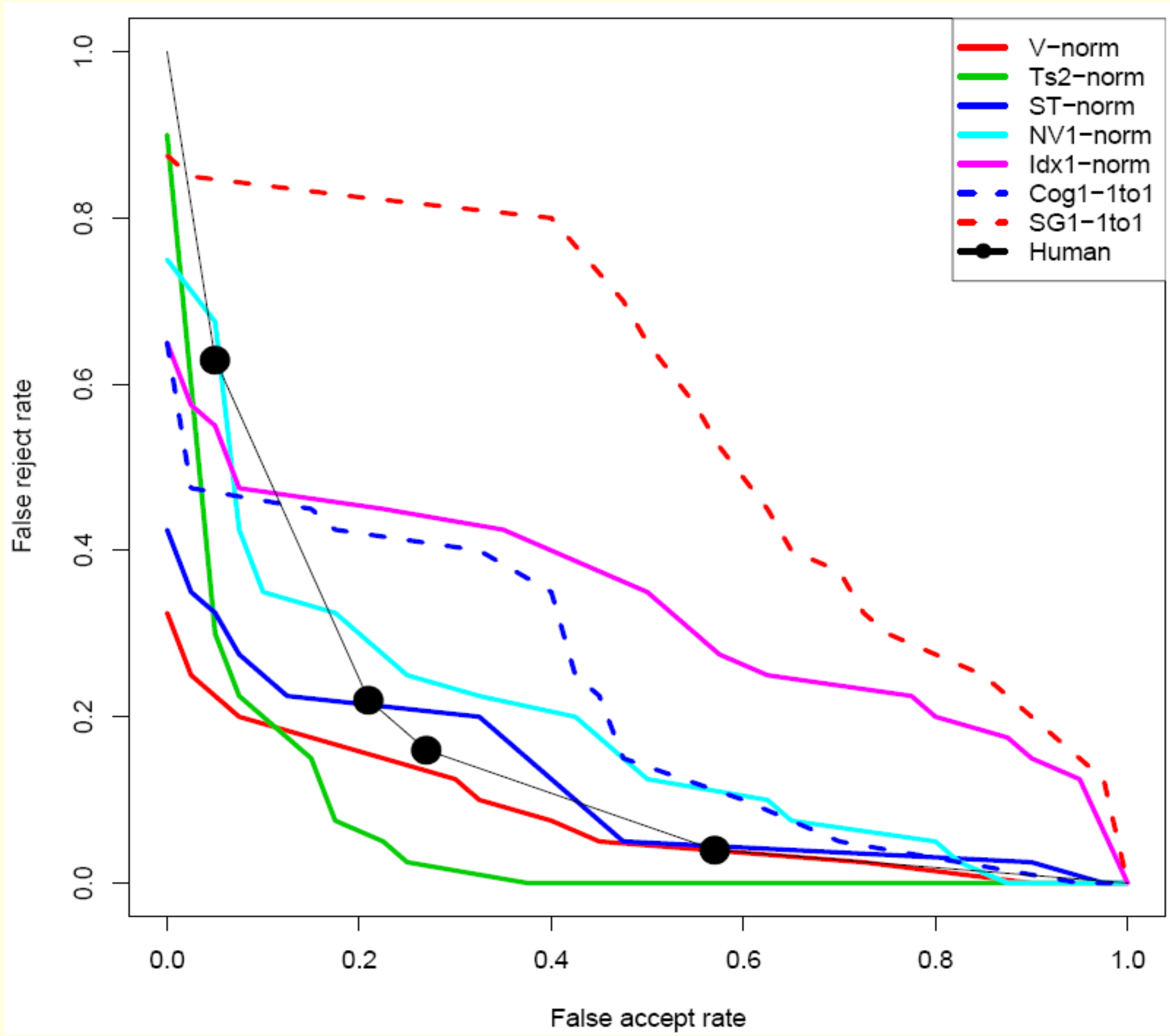
- **A methodology for classification evaluation based on expected cost of misclassification.**
  - *C(+|-)* denotes the cost of incorrectly classifying a genuine user (as an impostor)
    → Secondary inspection (False Non Match, FNMR).
  - *C(-|+)* denotes the cost of misclassifying an impostor as a genuine user.
    → Security breach (False Match, FMR).
  - *p(+)* probability of a user being an impostor.
  - *p(-)* probability of a user being a genuine.

Parameters considered

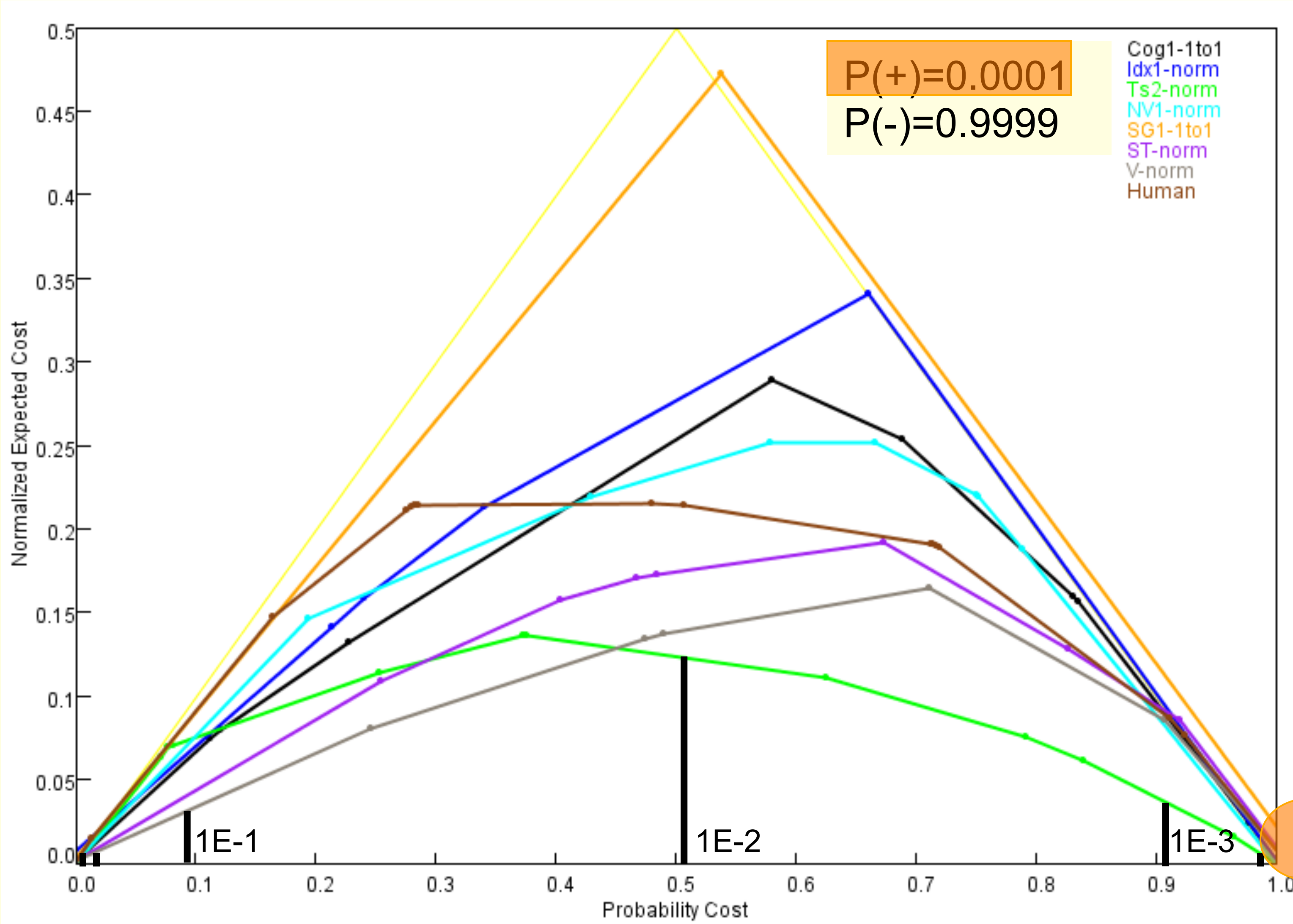
- **Which biometric modality (or algorithm) best meets the following operational conditions?**
  - Impostor arrival rate varies
    - One in thousand passengers (10^{-3})
    - One in hundred thousand passengers (10^{-5})
    - One in ten million passengers (10^{-7})
  - Misclassification cost ratio $\mu = C(+|-):C(-|+)$
    - It is 100 times more costly to miss an impostor (10^{-2})
    - 10,000 times more costly to miss an impostor (10^{-4})
    - 1,000,000 times more costly to miss an impostor (10^{-6})
    - 100,000,000 times more costly to miss an impostor (10^{-8})

Face Recognition for Border Inspections

2006 Face Recognition Vendor Test (FRVT)



Face recognition cost curves



Analysis Results

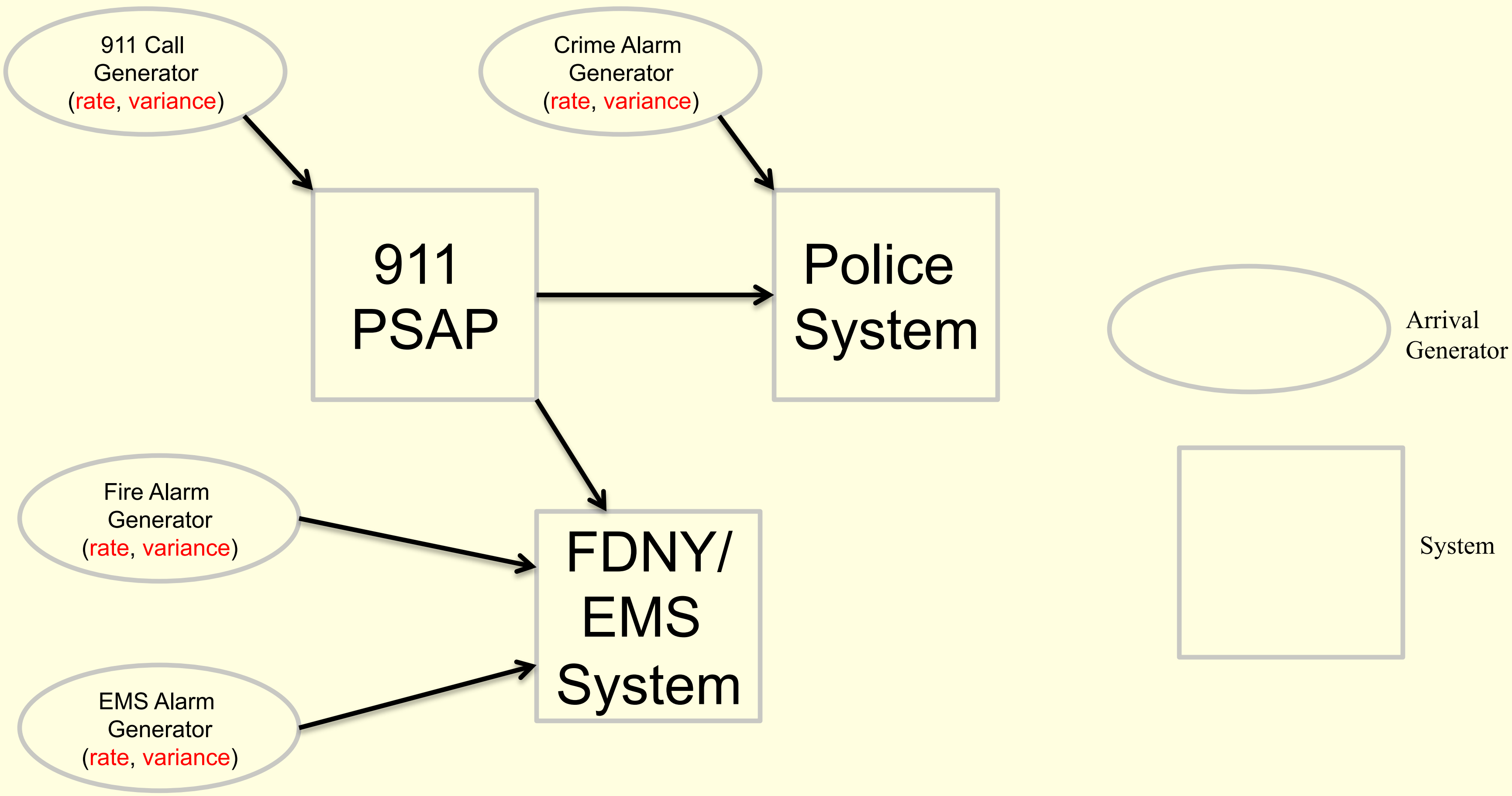
Table 3. Combined performance and risk modeling assuming the use of face biometrics

$p(+)$	μ	PC	$FNMR$	FMR	*Algorithm*	$Norm(E[Cost])$	*Total waiting time (min)*
10^{-3}	10^{-2}	0.090991811	0.00152	0.322	V-norm	0.030681056	31.87054
	10^{-4}	0.909173561	0.367	0.003	Ts2-norm	0.036060824	∞
			0.451	0.048	V-norm	0.0884	∞
			0.892	0	NV1-norm	0.0884	∞
	10^{-6}	0.999001997	0.451	0	Ts2-norm	0.000450099	∞
	10^{-8}	0.99999001	0.451	0	Ts2-norm	4.50544E-06	∞
10^{-5}	10^{-2}	0.000999011	0.00152	0.322	V-norm	0.001840163	27.93481
	10^{-4}	0.090909917	0.00152	0.322	V-norm	0.03065481	27.93481
	10^{-6}	0.909091736	0.367	0.003	Ts2-norm	0.036090608	∞
			0.451	0.048	V-norm	0.0884	∞
			0.892	0	NV1-norm	0.0884	∞
	10^{-8}	0.999001009	0.451	0	Ts2-norm	0.000450545	∞
10^{-7}	10^{-2}	9.9999E-06	0.00152	0.322	V-norm	0.001523205	27.89579
	10^{-4}	0.000999001	0.00152	0.322	V-norm	0.00184016	27.89579
	10^{-6}	0.090909099	0.00152	0.322	V-norm	0.030654548	27.89579
	10^{-8}	0.909090917	0.367	0.003	Ts2-norm	0.036090906	∞
			0.451	0.048	V-norm	0.0884	∞
			0.892	0	NV1-norm	0.0884	∞

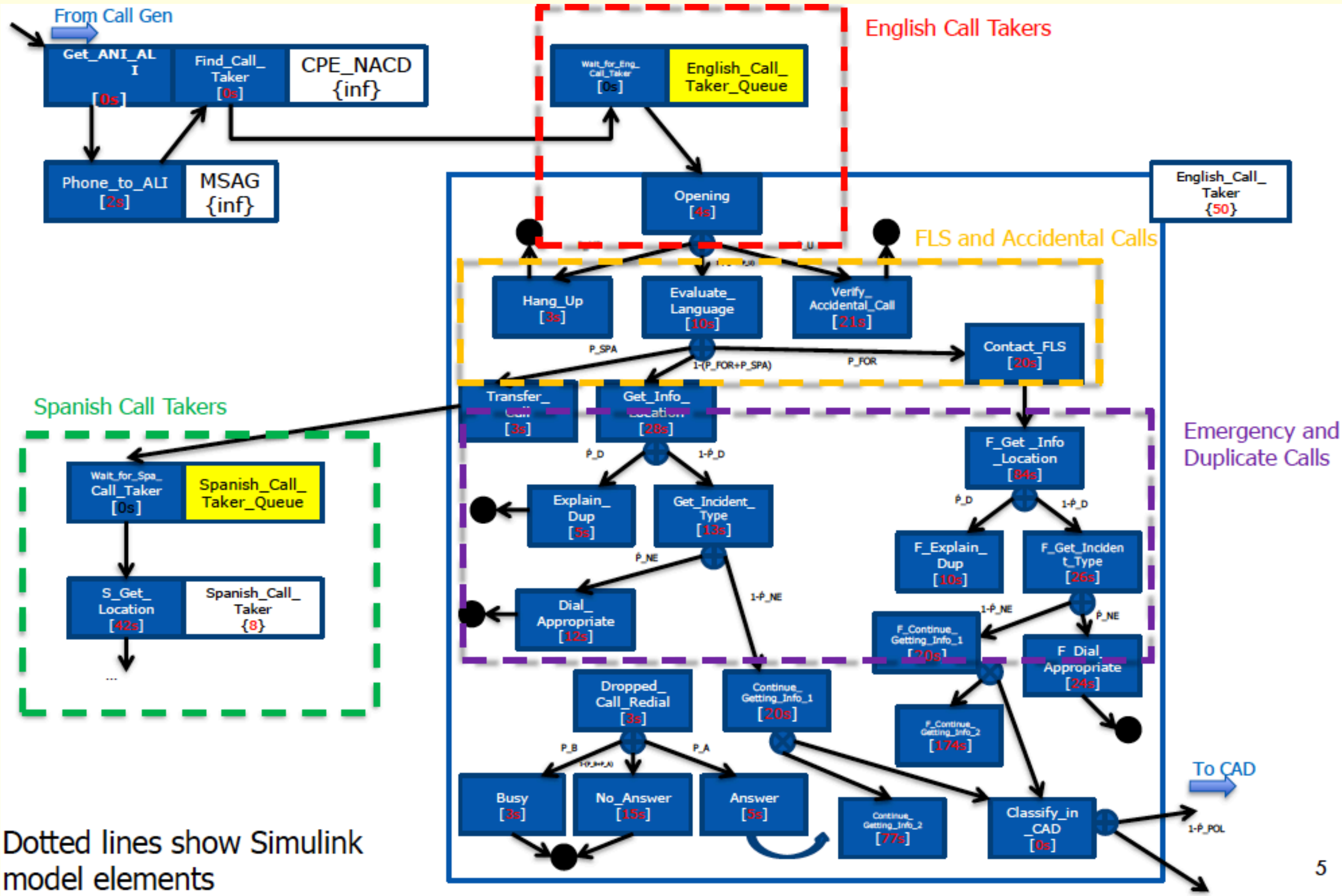
In feasible implementations, FMR is NOT ACCEPTABLE!

Application to ECTP

- **ECTP – Emergency Communication Transformation Program, revamped NYC 911 phone system.**

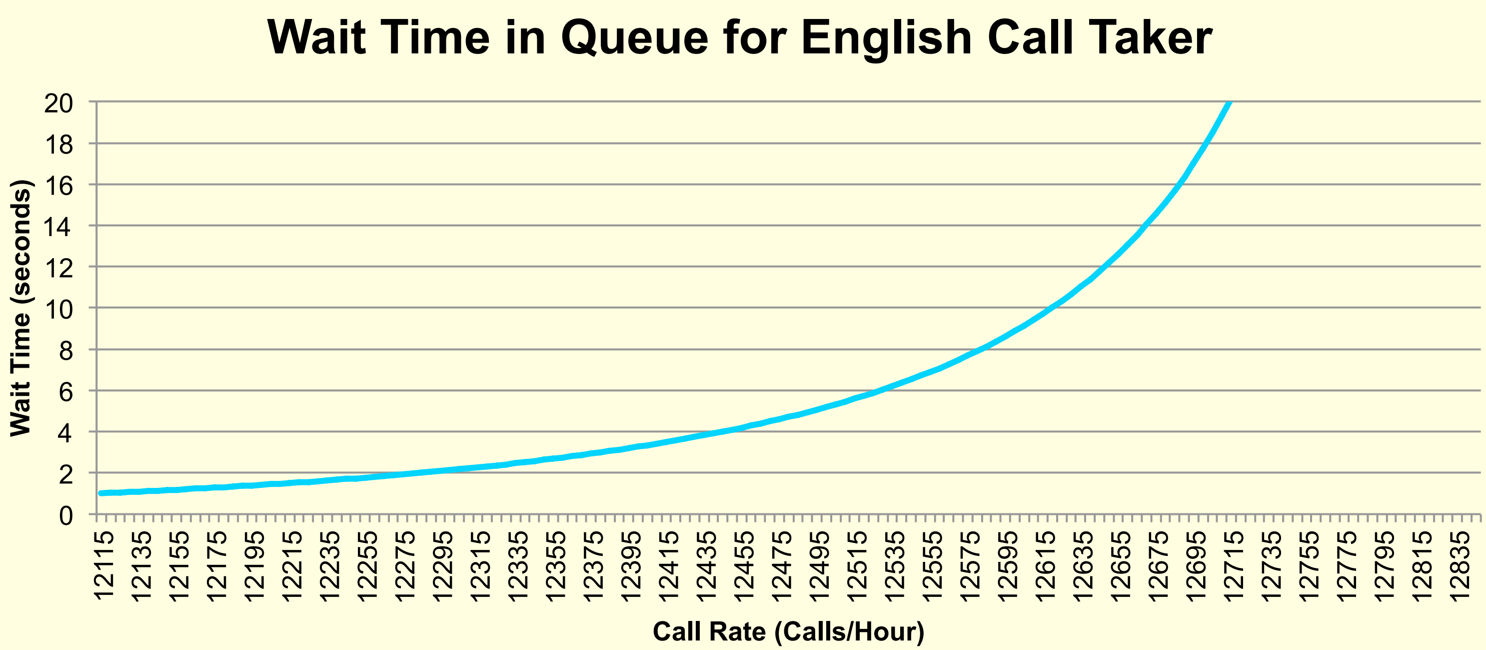


Complex Network (PSAP) Model



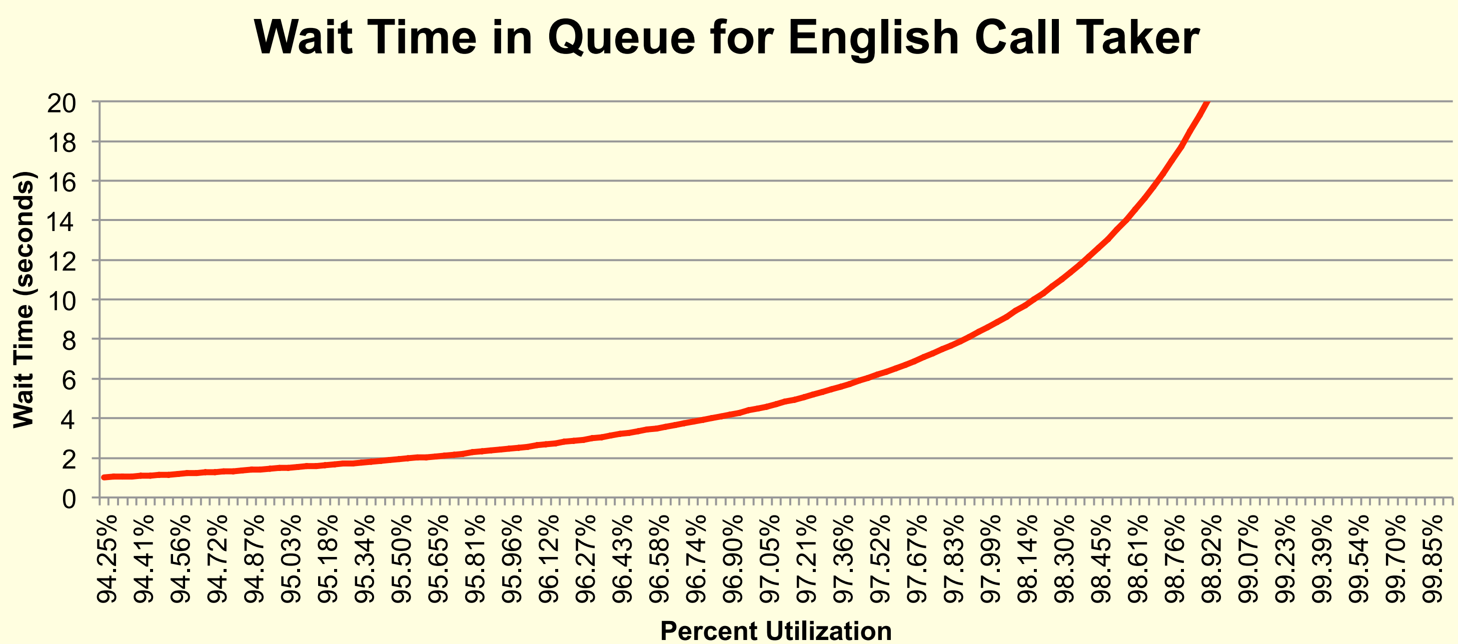
Dotted lines show Simulink model elements

Analysis



- **The average wait time surpasses 10 seconds at a call rate of 12620 calls/hour.**
- **Below 12115 calls/hour the wait time is less than one second.**
- **Below 10200 calls/hour there is never any wait time.**

Analysis
Waiting Time versus Utilization



- **With respect to utilization, wait time increases very late.**
  - Analysis scenario represents 321 English call takers.
  - Because it's such a high number, even around 95% average utilization it's rare to have a call come in when every call taker is busy.

Summary

- **Analytical performance models are very suitable for early system verification.**
  - Possible to create performance models from UML specs.
- **Queuing network models and tools are versatile.**
  - Reasonably quick learning curve.
  - Possible to build multi-level models in LQN.
  - Offer simulation capabilities for distributions that cannot be analytically solved.
- **Currently**
  - Updating the ECTP model, assessing its fidelity.
  - Enhancing simulation analysis (LQN-Sim, Simulink).
  - More detailed complex networks presentation tomorrow!